Planet Analog

PWM-controlled 4-20 mA current-loop transmitter provides galvanic isolation

By Alfredo H. Saab, Applications Engineering Manager, and Shasta Thomas, Customer Applications, Maxim Integrated Products Inc.
Planet Analog
Feb 24, 2009 (7:00 AM)
URL: http://www.planetanalog.com/showArticle?articleID=214502515

The accuracy of a 4-20 mA transmitter depends on the integrity of its current-loop path, which must be free of shunt paths and ground loops, both within the transmitter and external to it. External to the transmitter are spurious paths in the outside loop wiring and its power supply. Internal to the transmitter, shunt paths and ground loops are usually created at the point where you insert a control signal into the transmitter circuitry. To eliminate errors introduced by possible spurious current paths, the signal must be DC-coupled with full galvanic isolation, yet inserted with accuracy.

The circuit of **Figure 1** comprises a loop-powered 4-20 mA precision transmitter (MAX4236, BSP149, and MAX6138A) with large-compliance output stage, and a precision pulse width modulated (PWM) signal coupler, with galvanic isolation from the PWM signal source.

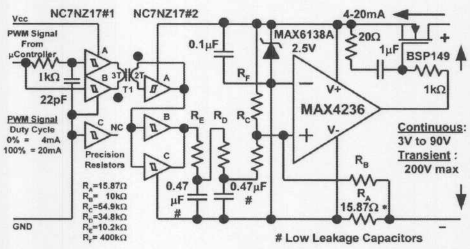

Figure 1: This loop-powered 4-20 mA transmitter features PWM drive and galvanic isolation from the input signal.
(Click on image to enlarge)

The external PWM-encoded signal is a rectangular waveform generated by a microcontroller or PWM modulator, and is usually produced by a control algorithm run by the microcontroller from a sensor output or other analog-command level. The input-signal duty cycle represents the original signal as a percentage of an arbitrary reference. In this case, the PWM-coupler values are adjusted so a 0% duty cycle corresponds to 4 mA from the transmitter, and a 100% duty cycle corresponds to 20 mA.

Sections A and B of the NC7NZ17#1 (a TinyLogic UHS triple buffer with Schmitt-trigger inputs) form a bipolar edge detector that applies a short, 20 ns pulse to the 3-turn primary of transformer T1. The polarity of this pulse depends on the sign of the input edge being detected.

At the secondary of T1, the pulse sets or resets the flip-flop formed by buffer #2A and the secondary, thereby replicating the input signal at the output of #2A. T1 is a 3-to-2-turn transformer built around a Fair-Rite ferrite core, type 2673000101. Its small size (3.5 mm diameter and 3.25 mm length) yields <1pF of capacitance at the primary and secondary. The maximum voltage it can withstand depends on the wire insulation used and the way T1 is mounted.

The two remaining buffer sections (B and C) are connected in parallel with their inputs attached to the flip-flop output. Their outputs produce a precision signal whose duty cycle replicates that of the input signal, yet provides precise and stable low/high values, thanks to the CMOS output that tracks the rail voltages exactly, and to the precision reference (MAX6138A) that serves as the transmitter power supply.

The paralleled buffer outputs drive a low-pass filter whose output is the average of the reconstituted PWM input signal, referred to the value of the transmitter supply voltage (the 2.5 V precision reference). This average value is a stable and very linear analog of the input signal's duty cycle. Fast propagation in the coupler (<30 ns H → L and L → H), and its small skew (<2 ns) ensure that negligible nonlinearity is introduced by the digital part of the coupler. The recovered average value drives the transmitter output, producing 4 mA at 0% duty cycle and 20 mA at 100%. For PWM input frequencies in the range of 500 Hz to 50 kHz, the circuit operates with less than 0.1% coupler insertion error.

After power-up, power-loss, or loss of input signal, the Figure 1 circuit's output state can remain undetermined until after the next input transition edge. The circuit of **Figure 2** removes that ambiguity with an "input-transitions loss detector."

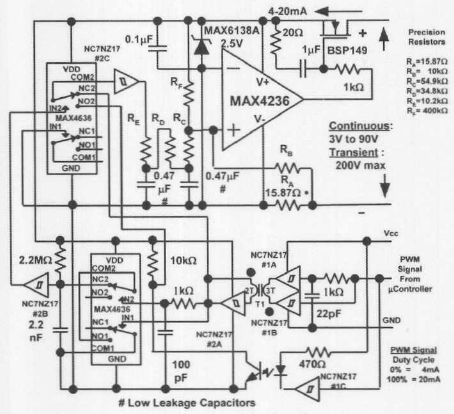

Figure 1: Adding a transitions-loss detector to the Figure 1 circuit eliminates the brief output uncertainty that can accompany power up, power loss, or loss of input signal.
(Click on image to enlarge)

When triggered by an interval of approximately 3 ms with no transitions, it connects the transmitter directly to the output of an optocoupler. The optocoupler senses the state of the input line at which it is resting, and imposes that state on the output current. That is, H state = 100% duty cycle → 20 mA, and L state = 0% duty cycle → 4 mA. Reasons for not using the optocoupler for PWM coupling include its much-longer propagation time, and its large, temperature-dependent propagation skew at any reasonably low levels of supply current.

The transitions-loss detector of Figure 2 consists of two analog switch ICs (MAX4636). The one in the lower half of the circuit discharges a 2.2 nF capacitor with every cycle of input signal. If a time interval longer than 3 ms elapses without a transition, the capacitor charges to a level that fires the Schmitt-trigger input of buffer #2B. In turn, this buffer drives the second analog switch (upper half of the circuit) to switch the input of buffer #2C from the PWM output of the coupler to the optocoupler output, thereby replicating the (now static) input line.

Also by these authors
•"Configure precision current-sink and current-source circuits as current mirrors or amplifiers", *Planet Analog*, click here

About the authors
Alfredo Saab, Applications Engineering Manager, joined Maxim Integrated Products in 1999. Prior to joining Maxim, he worked at the Stanford Linear Accelerator Center in Palo Alto, Calif., and at CERN in Switzerland. Additional jobs included work at the Bates Linear Accelerator at MIT in Cambridge, Mass., and Montagut Computacion S.A. in Buenos Aires, Argentina. He attended the University of Buenos Aires, studying electrical engineering and has a technical school degree in telecommunications.

Shasta Thomas, an associate member of the technical staff for Customer Applications, joined Maxim Integrated Products Inc. in 2006. She received a BSEE from San Jose State University in 2006.